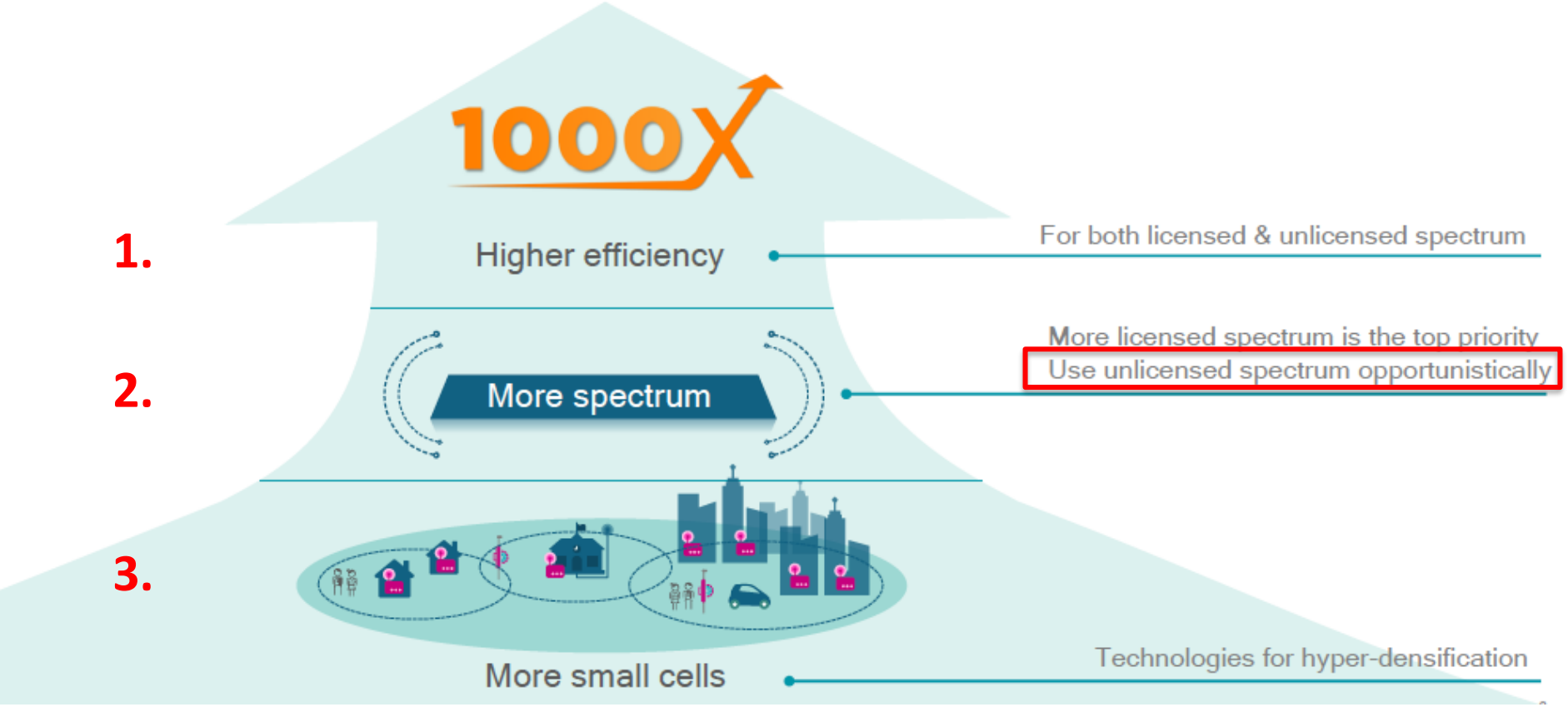
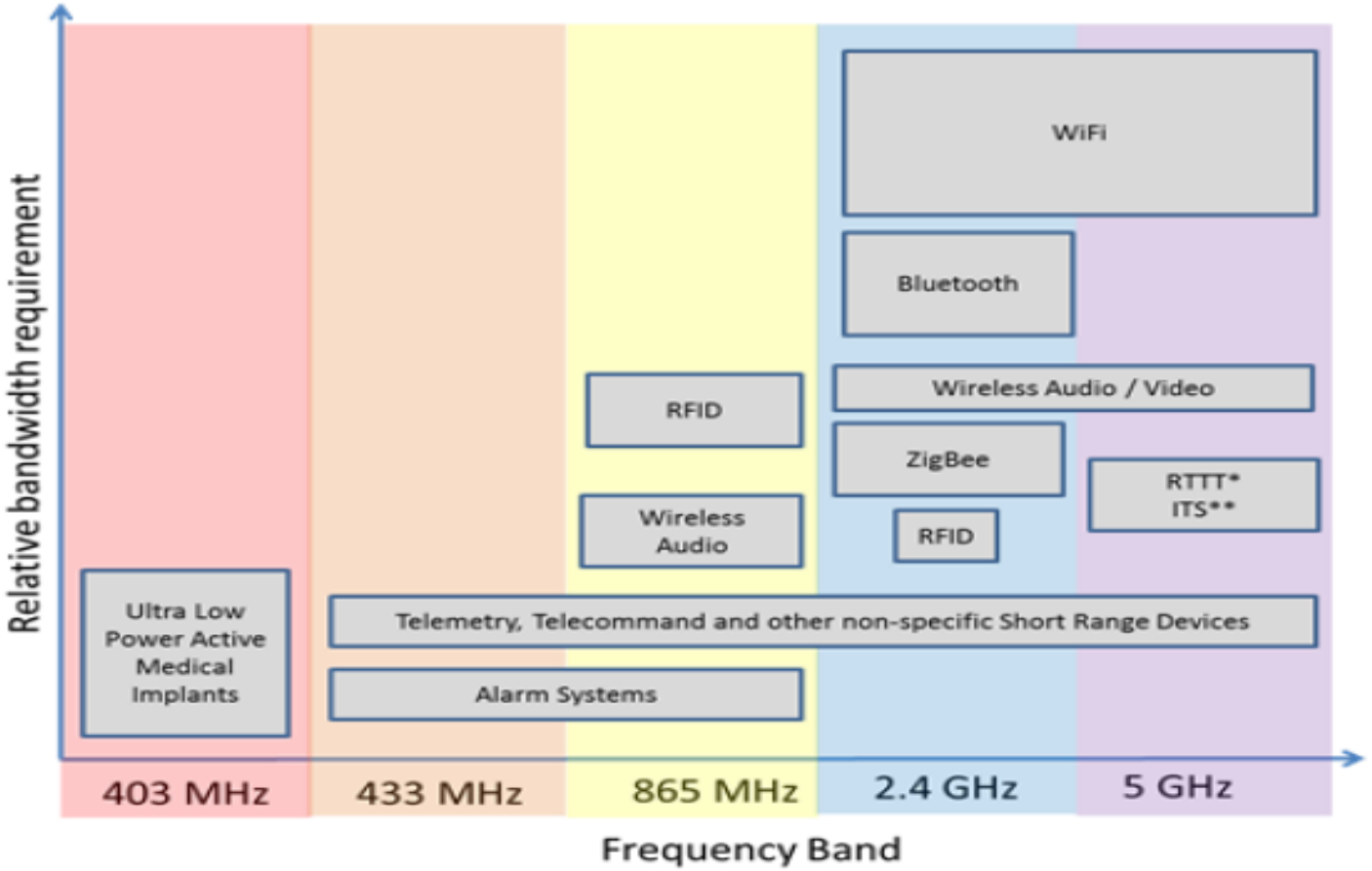
EEU44C04 / CS4031 / CS7NS3 / EEP55C27
Next Generation Networks

Spectrum Sharing

Nicola Marchetti
nicola.marchetti@tcd.ie


1000X
1.
Higher efficiency
For both licensed & unlicensed spectrum
2.
More spectrum
More licensed spectrum is the top priority
Use unlicensed spectrum opportunistically
3.
More small cells
Technologies for hyper-densification



*Road Transport and Traffic Telematics

**Intelligent Transport Systems

Benefits of unlicensed

- License-exempt bands provide significant benefits **for equipment vendors and service providers** in terms of:
  - **Facilitating market entry** – there is no need to acquire a license to deploy a service
  - Enabling niche applications or services to be addressed **quickly and cheaply** using existing technology and spectrum – this has been particularly effective in serving new machine to machine (M2M) applications in areas such as health, transport and home automation
  - Providing **certainty about spectrum access**
    - There is no need to compete or pay for spectrum access (though the collective nature of spectrum use means quality of service cannot be guaranteed)
    - Security of tenure – in general license exemption is not subject to an expiry date
  - **Reduced congestion in licensed bands** (e.g., through traffic offload from cellular networks to WiFi)
  - Ability to **extend the reach of fixed communication networks**, by providing wireless local area connectivity in homes, businesses and at public traffic hotspots

Benefits

- Key benefits from an **end user**'s perspective include:
  - Greater convenience and flexibility by **avoiding the need for lengthy runs of cable** in home and work environments
  - **Enhanced convenience**, safety and security, e.g., through installation of low-cost wireless alarm systems, or ability to unlock vehicles remotely rather than fumbling with keys
  - Ability to connect mobile devices to a fixed broadband network, **reducing dependence on the mobile network** and potentially saving costs both for the service provider and the end-user

European unlicensed uses

Band	Frequency Limits (MHz)	Applications
169 MHz	169.4 – 169.475	Metering Devices
403 MHz	401 - 406	Active Medical Implants
433 MHz	433.05 – 434.79	Non-specific SRDs
446 MHz	446 – 446.2	PMR 446
868 MHz	863 – 870 MHz	Non-specific SRDs
	863 – 865 MHz	Wireless microphones and assistive listening devices
	865 – 868 MHz	RFID
870 MHz	870 – 876 MHz*	Tracking, Tracing and Data Acquisition (TTDA)
		Transport and Traffic Telematics; Non-specific SRDs

Band	Frequency Limits (MHz)	Applications
915 MHz	915 – 921 MHz*	RFID
		Non-specific SRDs
		Assistive listening devices
1880 MHz	1880 - 1900	DECT
2.4 GHz	2400 – 2483.5 MHz	Wideband data transmission (e.g. Wi-Fi)
		Movement detection; Non-specific SRDs
	2446 – 2454 MHz	RFID
5 GHz	5150 – 5350 MHz 5470 – 5725 MHz	Wireless Access Systems (e.g. Wi-Fi)
5.8 GHz	5725 – 5875 MHz	Non-specific SRDs
	5795 – 5805 MHz	Transport and Traffic Telematics (TTT)
24 GHz	24 – 24.25 GHz	Non-specific SRDs
		Movement Detection
60 GHz	57 – 64 GHz	Non-specific SRDs
	57 – 66 GHz	Wideband data transmission (e.g. Wi-Gig)

PMR = Personal Mobile Radio
SRD = Short Range Device
DECT = Digital Enhanced Cordless Telecommunications

Rules for unlicensed

Band	Application(s)	Power Limit	Other mitigation requirements
433.05 – 434.79 MHz	Non-specific SRDs	10 mW	Duty cycle limits or max channel width of 25 kHz apply
863 – 870 MHz	Non-specific SRDs	25 mW	Duty cycle limits or LBT / AFA apply
863 – 865 MHz	Wireless microphones and assistive listening devices	10 mW	No other mitigation requirements
865 – 865.6 MHz	RFID	100 mW	200 kHz max bandwidth. No other mitigation requirements
865.6 – 867.6 MHz	RFID	2 W	200 kHz max bandwidth. No other mitigation requirements
867.7 – 868 MHz	RFID	500 mW	200 kHz max bandwidth. No other mitigation requirements
869.4 – 869.65 MHz	Non-specific SRDs	500 mW	Duty cycle limits or LBT / AFA apply
870 – 875.6 MHz	Tracking, Tracing and Data Acquisition	500 mW	Duty cycle limits and APC required. Wide area networks may require licence
870 – 875.8 MHz	Transport and Traffic Telematics	500 mW	Duty cycle limits and APC required. Highest power limited to vehicle to vehicle communication (100 mW otherwise)
870 – 876 MHz	Non-specific SRDs	25 mW	Duty cycle limits apply
915 – 921 MHz	RFID	4 W	May operate only when RFID tags present. 400 kHz max bandwidth. Detect and Avoid may be required above 918 MHz.
	Non-specific SRDs	25 mW	Duty cycle limits apply. 100 mW permitted on certain channels
	Assistive listening devices	10 mW	Specific sub-bands only. Duty cycle limit applies
1880 - 1900	DECT		
2400 – 2483.5 MHz	Wideband data transmission (e.g. Wi-Fi)	100 mW	Spectrum sharing mechanism (e.g. LBT or DAA) required. 10 mW/MHz max PSD
	Movement detection	25 mW	No other mitigation requirements
	Non-specific SRDs	10 mW	No other mitigation requirements

Band	Application(s)	Power Limit	Other mitigation requirements
2446 – 2454 MHz	RFID	500 mW	No other mitigation requirements
		4 W	Duty cycle limit applies. FHSS must be used. Indoor use only
5150 – 5250 MHz	Wireless Access Systems (e.g. Wi-Fi)	200 mW	Indoor use only. 10 mW/MHz max PSD. No other mitigation requirements
5250 – 5350 MHz	Wireless Access Systems (e.g. Wi-Fi)	200 mW	Mitigation techniques at least as effective as those in EN 301 893 required. Indoor use only. 10 mW/MHz max PSD
5470 – 5725 MHz	Wireless Access Systems (e.g. Wi-Fi)	1W	Mitigation techniques at least as effective as those in EN 301 893 required. 50 mW/MHz max PSD
5725 – 5875 MHz	Non-specific SRDs	25 mW	No other mitigation requirements
5795 – 5805 MHz	Transport and Traffic Telematics	2 W	Higher powers (up to 8W) may require licence. No other mitigation requirements
24 – 24.25 GHz	Non-specific SRDs	100 mW	No other mitigation requirements
57 – 64 GHz	Non-specific SRDs	100 mW	Max.10 mW input to antenna; PSD 10 mW/MHz max. No other mitigation requirements
57 – 66 GHz	Wideband data transmission (e.g. Wi-Gig)	10 W	Spectrum sharing mechanism (e.g. LBT or DAA) required. 20 mW/MHz max PSD, No fixed outdoor use

Why so many rules?

Co-existence with other *like* devices.

Co-existence with other *different* systems.

CSMA/CA = Carrier Sense Multiple Access / Collision Avoidance

WiFi

- Wi-Fi (Wireless Fidelity) is the wireless broadband data technology based on the IEEE 802.11 series of standards, whose main use is providing **wireless broadband connectivity to fixed or mobile user devices**
- The 802.11 series of standards has been developed over the last 25 years by the *US-based* IEEE standards body
- CSMA/CA interference mitigation is a key feature of the 802.11 standards, and is intended to facilitate equitable spectrum access between multiple Wi-Fi systems even in highly contended environments
- When we discuss WiFi, think also of 5G
  - **If 5G wants to use this spectrum it must also abide by the rules applicable to WiFi** → <u>They are the same *type* of use</u>

WiFi: 1Gbps, MIMO

- 802.11n variant which may be either single (2.4 GHz) or dual (2.4 / 5 GHz) band and incorporates additional enhancements such as MIMO antennas and the use of wider (40 MHz) channels, extending the theoretical over-the-air bit rate to as high as **600 Mbps**

- Further enhancements are embodied in the **802.11ac** standard, notably the ability to use even wider channels (**80 or 160 MHz**), higher level modulation (**256QAM**) and up to eight MIMO streams to extend the theoretical over-the-air bit rate to well over **1 Gbps**

WiFi: M2M, < 1GHz

- More recent enhancements to the 802.11 standards extend the capability to lower and higher frequency bands

- **802.11ah**
  - primarily aimed at **M2M** and other relatively low bit rate applications…
  - …but may also be used to extend the coverage of broadband Wi-Fi connections by using sub-1 GHz spectrum
  - provides bandwidth options of 1, 2, 4, 8, and 16 MHz

WiFi: 60GHz, ~ 7Gbps

- **802.11ad**, also referred to as **Wi-Gig**, operates in the 60 GHz millimetre wave band and is intended for very high-speed, short-range applications

- The 60 GHz band is particularly attractive, having a total of 8 GHz of contiguous spectrum available in all EU Member States

- Suggested **applications** include cable replacement for displays, wireless docking between devices like laptops and tablets, *instant* data synchronisation and backup, and simultaneous streaming of multiple, ultra-high definition and 4K videos → Standard is intended to **deliver multi-Gigabit speeds with very low latency**

WiFi: 60GHz, ~ 7Gbps

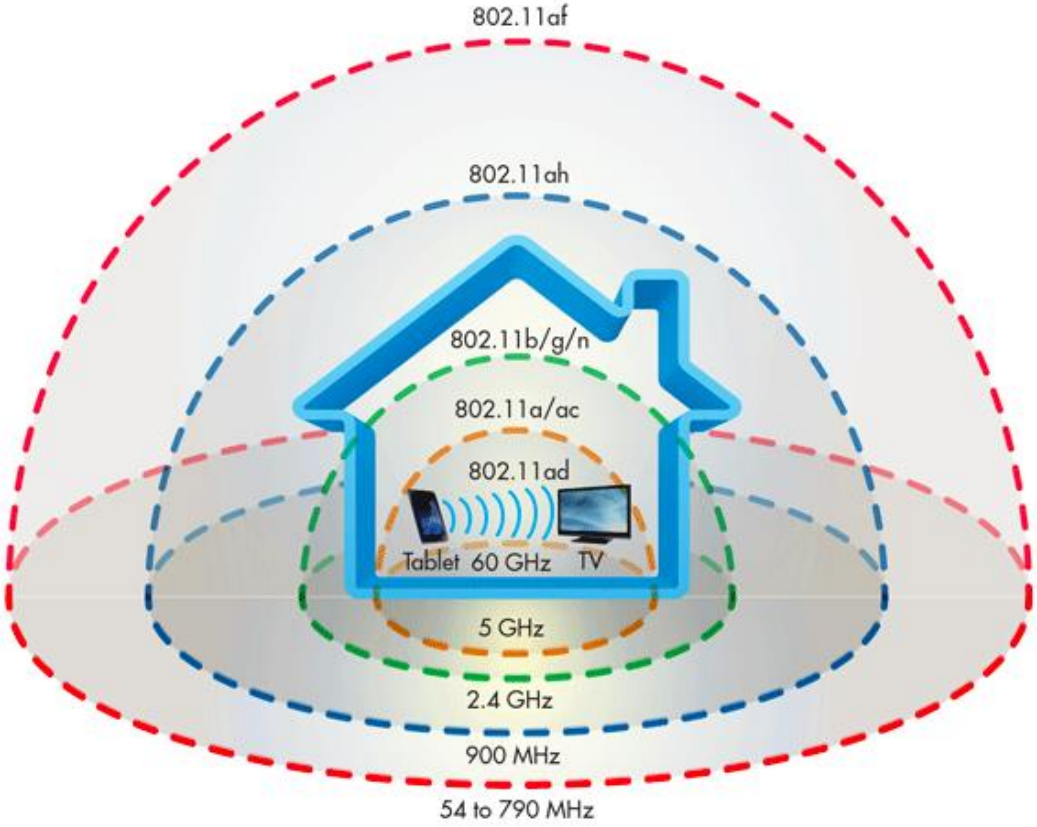
- Routers on the market

- The standard is expected to deliver speeds of up to 7 Gbps over ranges of up to **10 metres** → in practice this is likely to be within a single room as most building materials have very high attenuation at these high (mmWave) frequencies

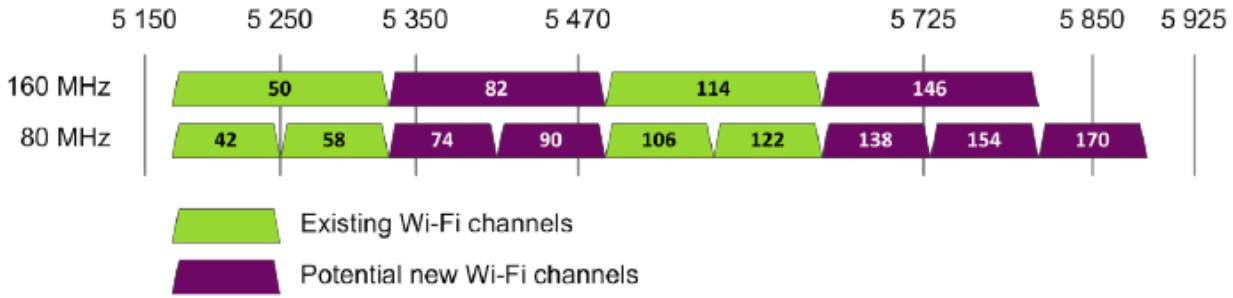
WiFi: 60GHz, > 30Gbps

- **802.11ay** developed by the IEEE and aims at data rates in excess of **30 Gbps**
- Potential applications include line of sight wireless backhaul (extended transmission distance of 300–500 metres) and high-speed content downloads over very short ranges
  - Similar to today's contactless smart card technology, but enabling a full-length movie to be downloaded in under a second
  - What's the use of that????? ☺
- Note: all new standards are brought within the ambit of the Wi-Fi Alliance → Global industry body which plays a leading role in overseeing certification and interoperability of Wi-Fi products

WiFi by range



5GHz – potentially **720 MHz** available



**WiFi – or any broadband technology adhering to the rules such as LTE*

5GHz – the promised land of unlicensed capacity

- Why this band?
  - Trade-off between capacity and coverage
  - At these frequencies, a small cell can serve a full room or a few rooms (building material-dependent)
  - 5 GHz is relatively underutilized ***for now***
  - 60 GHz doesn't offer useful coverage *yet*
    - More difficult to address mobile users/uses

Making best use of 5 GHz unlicensed band

LTE-U/LAA, LWA, MulteFire and 802.11 ac/ax will coexist in 5 GHz

Enterprises

Small Businesses

Venues

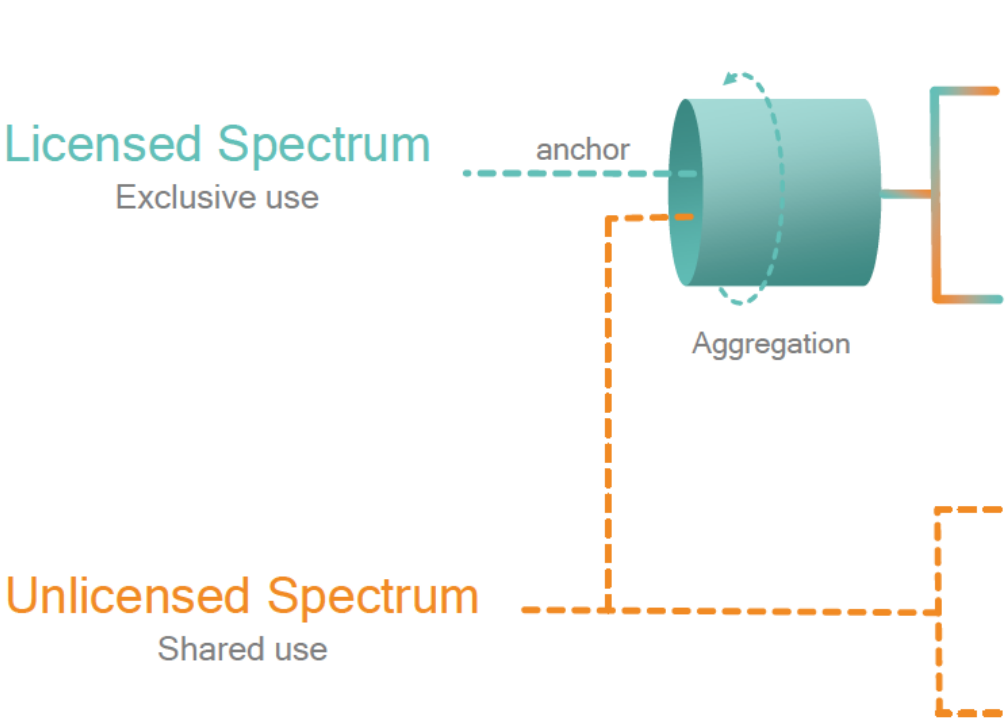
Residential/ Neighborhood

Large amounts of spectrum available globally (~500 MHz)

Ideal for small cells thanks to lower mandated transmit power

Global neutral spectrum that can serve any user with same deployment - neutral hosts

Multiple technologies will coexist in unlicensed spectrum



LTE-U / LAA[1]

Cellular in licensed + unlicensed

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA[2] / LWIP[3]

Cellular + Wi-Fi in licensed + unlicensed

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

Cellular in unlicensed

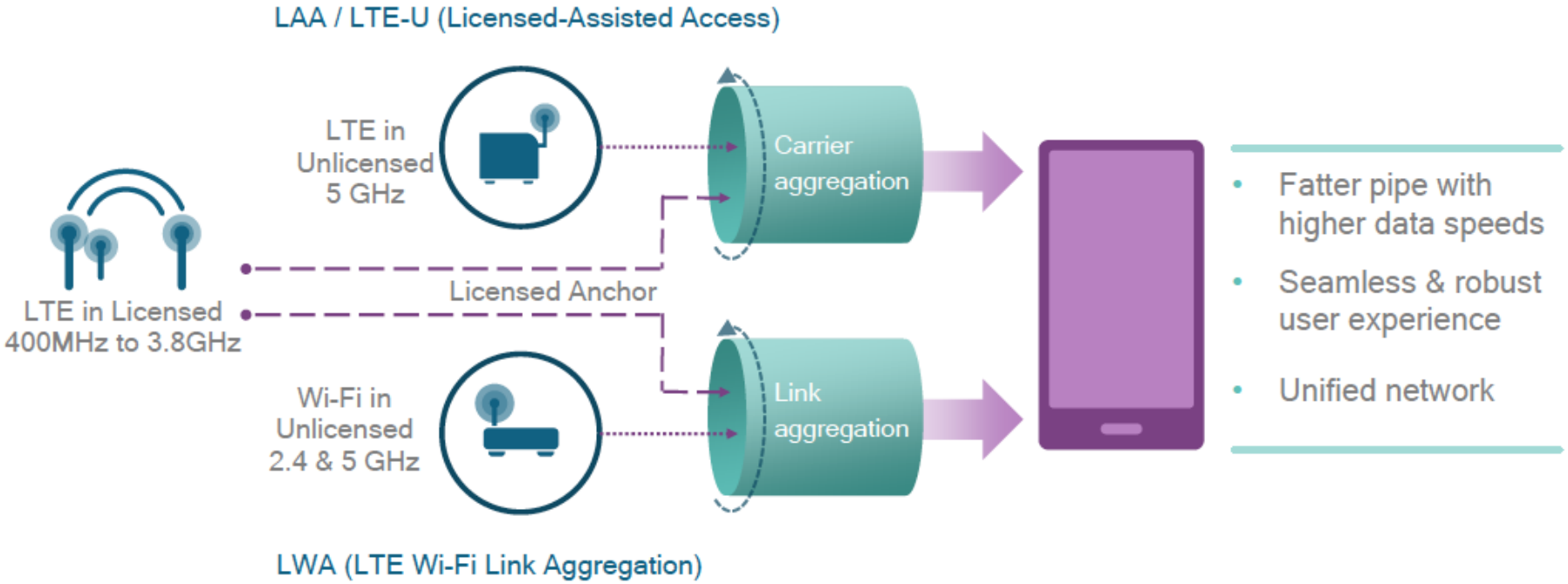
Broadens LTE ecosystem to enhanced and new deployment opportunities, suitable for neutral host

Wi-Fi[4]

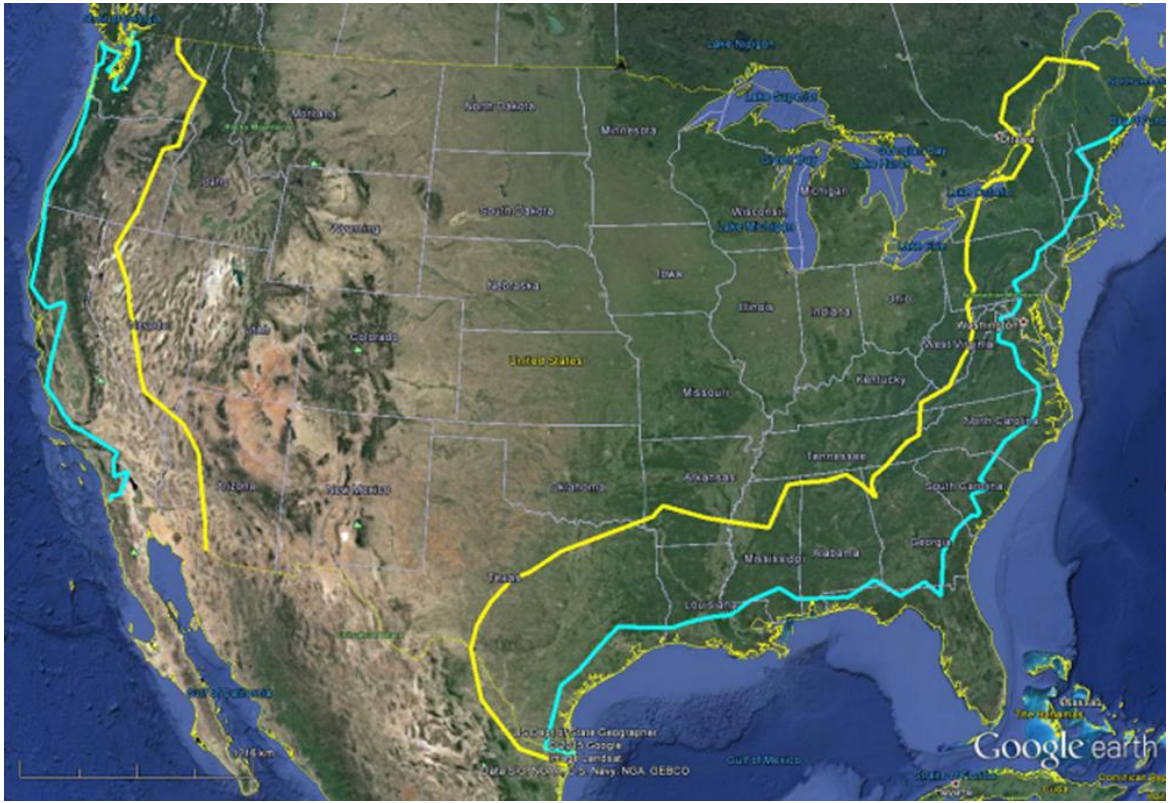
Wi-Fi in unlicensed

Evolving for enhanced performance and expanding to new usage models, used today as neutral host

1) Licensed-Assisted Access (LAA), also includes enhanced LAA (eLAA); 2) LTE Wi-Fi Link Aggregation (LWA); 3) LTE Wi-Fi radio level integration with IPsec tunnel (LWIP); 4) 802.11ac / .11ad / .11ax / .11ay


LAA / LTE-U (Licensed-Assisted Access)
LTE in Unlicensed 5 GHz
Carrier aggregation
LTE in Licensed 400MHz to 3.8GHz
Licensed Anchor
Wi-Fi in Unlicensed 2.4 & 5 GHz
Link aggregation
LWA (LTE Wi-Fi Link Aggregation)
Fatter pipe with higher data speeds
Seamless & robust user experience
Unified network

Sharing the 3.5GHz band

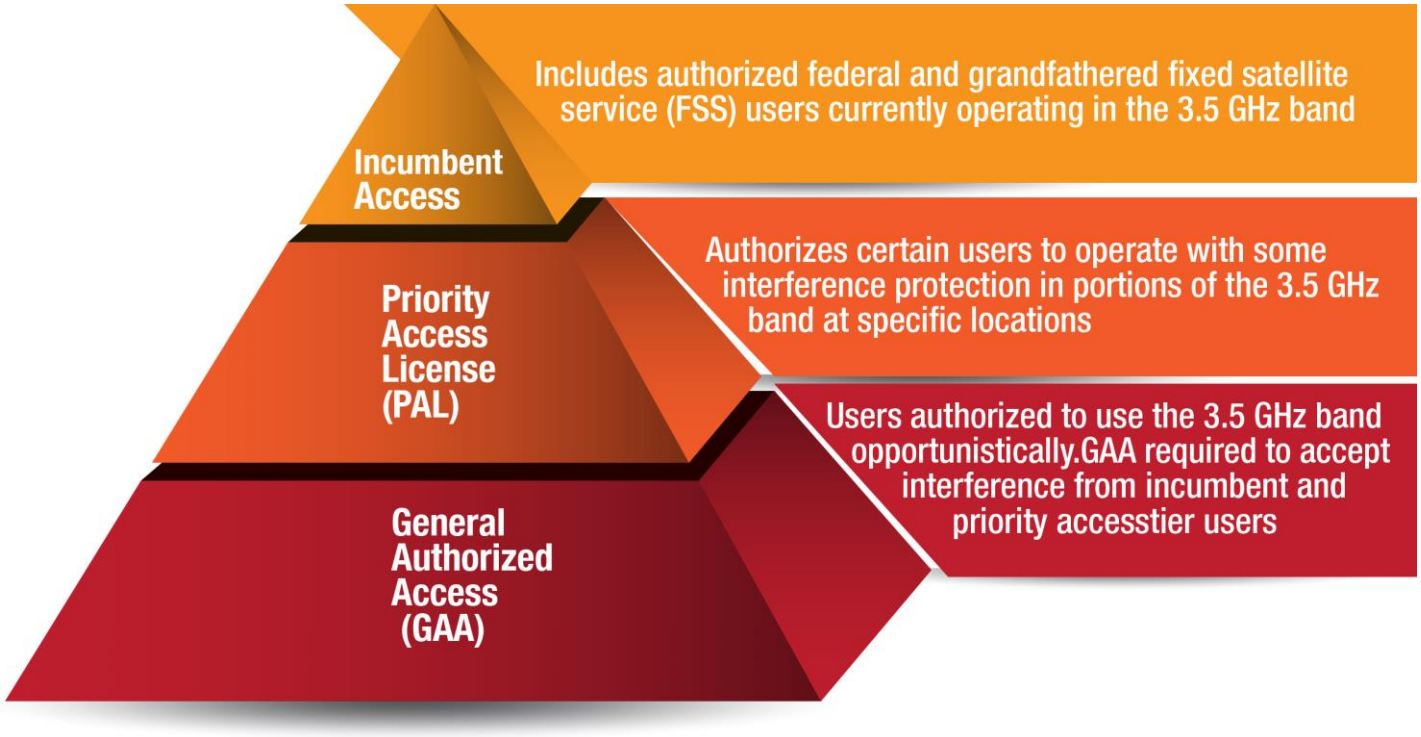


US National Telecommunications and Information Administration (NTIA)

Yellow – initial exclusion area to protect coastal radar @3.5GHz and Fixed Satellite Services (FSS) ground stations

Cyan/blue – final exclusion zone

Spectrum Access System (SAS) @USA



Which one among the following bands is the most relevant in the context of cognitive radio systems coexistence with radar systems?

- ❑ 400 MHz
- ❑ 3.5 GHz
- ❑ 60 GHz

Which one among the following bands is the most relevant in the context of cognitive radio systems coexistence with radar systems?

- ❑ 400 MHz
- ❑ **3.5 GHz**
- ❑ 60 GHz